FY 2006 Theory 05-08 Solicitation Results

Title	Principal Investigator	Institute	Abstract
Transients and Magnetic Relaxation in Innovative Confinement Concepts	C. Sovinec	University of Wisconsin-Madison	With peak temperatures at hundreds of electron-Volts, time-scales in smaller magnetically confined plasmas are not as well separated as they are in high-performance tokamaks. In addition, current profile may be driven through nonlinear dynamo activity, which is not as easily controlled as auxiliary drive in large devices. These two facts lead to important interactions between magnetic relaxation and global transients. Here, we propose to apply nonlinear numerical computation to this class of macroscopic dynamics in reversed-field pinches (RFPs), spheromaks, and spherical tori (ST). For RFPs, our effort will investigate edge fluctuations and the formation of quasi-single-helicity states during pulsed parallel current drive; for spheromaks, the cause and effect of resonant modes during high-confinement conditions; and for ST, the transition from electrostatic to Ohmic current drive.
Alpha Channeling in Mirror Machines	N. Fisch	Princeton University	Mirror machines would be an attractive reactor concept from an engineering standpoint if only the Q of the reactor were larger. This proposal seeks to evaluate whether by means of alpha channeling the effective reactivity, and hence the effective Q, of the mirror machine might be doubled, thereby making the concept competitive and possibly very attractive. The proposal will involve the identification of suitable plasma waves and methodologies to conceive in mirror machines what has already been predicted for tokamaks, but here, as opposed to the situation for tokamaks, the doubling of the effective reactivity would be the most critical issue.
Physics of High Energy Plasmas	B. Coppi	Massachusetts Institute of Technology	The Physics of High Energy Plasmas effort at M.I.T. has a long and deep history in plasma physics. The main direction of this effort is the theoretical understanding of the collective models that can play a key role in the dynamics of fusion burning plasmas and in determining their transport processes. Since these modes can be microscopic (e.g., the 1/1 mode producing sawtooth oscillations), we employ the complete range of theoretical descriptions, both linear and nonlinear, from phase space equations to two-fluid equations. We have developed global simulation models employing advanced computational techniques for this. Important processes occurring in existing experiments have been identified, as in the case of the spontaneous rotation phenomenon in toroidal plasmas, and their relevant theoretical background has been developed. We also use the theoretical techniques and concepts originating from fusion research to deal with important issues in space physics and astrophysics, such as the equilibrium configurations of plasma accretion disks and the characteristic collective modes needed to produce a significant rate of angular momentum transport in them. Our ac
Equilibrium Reconstruction and Magnetic Field Studies in Stellarators	J. Hanson	Auburn University	Equilibrium reconstruction is the process of inferring the radial profiles of an MHD equilibrium model by minimizing the mismatch between model-calculated and observed diagnostic signals. The code EFIT, which does equilibrium reconstruction for axisymmetric systems, has proven invaluable for the interpretation of tokamak experiments. The V3FIT code will provide a fast, flexible equilibrium reconstruction capability for stellarator (non-axisymmetric) plasmas. V3FIT is currently under construction, and when operational, should prove to be the premier equilibrium reconstruction code for the worldwide stellarator community. The main proposal task is to continue development of V3FIT, and to benchmark and verify the operation of V3FIT in conjunction with the Compact Toroidal Hybrid (CTH) stellarator experiment at Auburn. In addition to work on V3FIT, a portion of the proposal task will be to provide theoretical and computational support to the CTH experiment, particularly in the area of magnetic field error correction coil design and operation.

Theoretical Research in Advanced Physics and Technology	P. Catto	Massachusetts Institute of Technology	The plasma theory research proposed will be performed by the theory group at the MIT Plasma Science and Fusion Center in support of the national and international magnetic fusion programs, as well as the Alcator C-Mod (C-Mod) and the Levitated Dipole Experiment (LDX). The research is to be performed under four task headings: (i) MHD and Stability, (ii) Heating and Current Drive, (iii) Confinement and Transport, and (iv) LDX and Innovative Concepts. Task (i) will focus on neoclassical tearing modes, resistive ballooning modes, and fluid closure in the presence of collisions; while task (ii) will investigate ICRF mode conversion flow and current drive, lower hybrid and ion cyclotron current drive, as well as electron Bernstein wave propagation, damping, current drive, and coupling to high harmonic fast waves. Trapped electron modes, streamers, angular momentum pinches, magnetic topology effects on flows, and hybrid fluid-kinetic closure for arbitrary collisionality will be examined in task (iii). For task (iv) we will continue
Resistive Wall Modes and Error Field Amplication	A. Boozer	Columbia University	The attractiveness of tokamaks for fusion applications is limited by kink instabilities that would be stabilized if the surrounding chamber walls were perfectly conducting. These instabilities, called resistive wall modes, can be stabilized by feedback or by mode rotation. A closely related phenomenon is the amplification of magnetic field errors as a plasma approaches marginal stability. Our work on resistive wall modes and error field amplification is in collaboration with related research at Columbia: with Jim Bialek on extensions to the VALEN code and with the HBT-EP experimental group. The extensions to VALEN that will be performed in collaboration with Jim Bialek are: (1) the implementation of a full multimode capability, (2) the inclusion of mode rotation effects, and (3) the inclusion of the inertial effects that are important near marginal stability for the ideal mode. Comparison with experiments will be made through our collaborations with the HBT-EP, DIII-D, and NSTX groups.
Basic Physical Processes Involving Dust in Fusion Plasmas	S. Krasheninnikov	University of California, San Diego	The study of dust in magnetic controlled fusion devices is a new area of research. It is now well established that dust (small particulates ranging in size from several tens of nanometer to millimeters) can occur in fusion devices. There could be many consequences of dust for plasma operation and performance, including possible effects on core plasma contamination and plasma stability as well as important safety issues. Because this research area is so new, the physical processes governing the interaction of the dust with the plasma, the subsequent dynamics and transport of the dust, as well as the effects of dust on plasma operation, are as yet not well understood. The goals of this proposal are: i) to study theoretically the basic physics of dust in fusion plasmas, and develop models for dust charging and processes relevant to the momentum, energy, and mass balance of dust; ii) to develop the computer code, which would allow us to incorporate all the above effects for real tokamak edge plasma parameters and geometry; and iii) to apply this code to model dust dynamics, transport, and impact on core plasma, as well as to verify our theoretical models against experimental data.
The Theory of Electron-Ion Collisions	D. Griffin	Rollins College	Over the last few years, we have made significant progress in the development of efficient parallel R-matrix codes that allow us to treat electron-impact excitation and ionization with much greater accuracy than ever before. During the next three years, we are planning to apply these methods to more complex targets. In addition, with the progress we are now making in the development of parallel Dirac R-matrix codes, we will be able to treat electron-impact excitation of heavy species in higher stages of ionization. We will also continue work on the parallel BP and Dirac R-matrix codes to further improve their efficiency and to incorporate radiation damping, which can become important in highly ionized species. Finally, we will make these data available to the fusion community on the Web and employ them to carry out collisional-radiative studies in support of various fusion experiments.

MHD Stability of Compact Stellarators and Transport Dynamics in Toroidal Confinement Devices	A. Ware	University of Montana	This project involves theoretical and computational calculations of the magnetohydrodynamic (MHD) equilibrium and stability properties of stellarators and numerical studies of transport dynamics in toroidal confinement devices. The focus of the MHD equilibrium and stability work will be on (1) local and global calculations of ballooning stability in three-dimensional plasmas, (2) a study of the impact of three-dimensional geometry on ballooning stability, and (3) inclusion of finite-Larmor radius effects on the stability and mode structure of localized ballooning modes.
Basic Research in Magnetically Confined Fusion Plasmas	D. D'Ippolito	Lodestar Research Corporation	In recent years, the Lodestar research program in fusion theory has emphasized two general areas: (i) understanding the unique properties of the tokamak boundary plasma (including equilibrium, stability, turbulence and transport); and (ii) nonlinear interactions of plasma with radiofrequency (rf) waves. It is proposed here to extend our work on three related themes: (1) the equilibrium, stability and turbulence properties of the edge/SOL plasma including dissipative and X-point effects; (2) convective transport of particles, energy and momentum by coherent propagating objects (curvature-driven blobs and rf-sheath driven convective cells) and the consequences of this transport; and (3) nonlinear effects of large-amplitude rf waves in plasmas (ponderomotive, sheath, and parametric instabilities) and the consequences of these effects on ICRF wave coupling to turbulent fusion plasmas. In each of these areas, our approach is to use analytic and reduced numerical models to study the physical mechanisms and then to test our models
Theory of Field Reversed Configurations	L. Steinhauer	University of Washington	The overall objective of the proposed research is to advance the scientific understanding of FRCs as a innovative confinement concept. Its focus is on the critical issues for FRCs: equilibrium and stability. Practical methods for finding flowing equilibria will be developed, building on the formalism developed in previous phases of the program. The outcome will be to explain the detailed properties of realistic two-dimensional FRC equilibria with strong flows. These models will be applied as an interpretive tool to explain the physics of the companion experiments. The nonlinear stability of FRCs will be explored using the Fourier-Beltrami expansion technique, an effort begun during the previous phase of the program. This is a computationally-modest method for modeling the complicated nonlinear dynamics of plasma evolution. The stabilizing influence of flows, especially rotation, will be determined. These results should resolve the long-standing question of why the virulent tilt instability is not observed in most experiments. The proposed research will emphasize analytic and quasianalytic